

SECTION 02395
CONCRETE DIAPHRAGM (SLURRY) WALLS

PART 1 - GENERAL

0.1 DESCRIPTION OF WORK

- A.** Work Included: This Section specifies construction of concrete diaphragm walls by the bentonite slurry trench method.
- B.** Related Work: The following items are not included in this Section and will be performed under the designated Sections:
 1. Section 03300 - CAST-IN-PLACE CONCRETE; for requirements of concrete work, including reinforcement, except as modified herein.
- C.** Where the design of the walls, or any details thereof, are not indicated, the Contractor shall be responsible for such design, in accordance with design criteria and loads indicated. Where methods of construction or any details thereof, are not indicated, they will be at the Contractor's option, subject to applicable codes, Contract requirements, and review and acceptance by the Engineer.

0.2 SUBMITTALS

- A.** Shop Drawings. Submit shop drawings showing configuration and details of completed guide walls and diaphragm walls, including the following:
 1. Guide wall details, showing reinforcing if used, width and height.
 2. Reinforcing steel cages, including provision for lifting, stiffening, splicing, tieback setting, corrosion control, and orientation of the cage with respect to the wall.
 3. Beam and slab anchorage details.
 4. Details of plates, sleeves, pipes, and other embedded items, and requirements for instruments and utilities to be installed in or through the wall.
 5. Structural steel sizes and splice details of soldier pile walls.
- B.** Working Drawings. Submit working drawings showing proposed equipment and methods of construction, including the following:
 1. Schedule of guide trench construction and utilities relocation.
 2. Sequence and schedule of construction of the various panels of the diaphragm walls.
 3. Methods of excavation and vibration control through overburden, including glacial till with cobbles and boulders, through rock

weathered to different degrees and through sound bedrock. Include estimated rates of excavation through the various materials.

4. Method of bentonite slurry preparation, site distribution, reclamation and disposal.
5. Slurry mix composition, and methods of monitoring and testing to comply with requirements specified herein.
6. Method of monitoring and maintaining slurry level in excavations left open overnight or over an extended period of time.
7. Method of maintaining stability of excavated trenches in case of sudden loss of bentonite suspension.
8. Method of monitoring plumbness and deviation of wall panels during excavation and details of proposed corrective measures to be implemented if necessary.
9. Equipment and method of checking and proving the cleanliness of trench bottoms and soundness of foundation material, prior to concreting.
10. Method of forming recesses.
11. Method of forming and cleaning joints between adjacent wall panels, including method of checking plumbness and deviation, and details of corrective measures to be implemented if necessary.
12. Method of installing and securing reinforcing steel cages.
13. Method of concreting.
14. Measures to protect the public and surrounding property from hazards inherent in the operations, including leakage and spillage of slurry, and falls into open guide trenches or excavated wall panels.

C. Manufacturers' Product Data. Before using any of the following products in the work, and whenever a product is changed, submit manufacturers' specifications, test reports, instructions, and other information as may be requested by the Engineer including the following:

1. Fly ash
2. Plasticizing admixture
3. Bentonite
4. Bentonite additives

D. Qualifications of bentonite slurry trench contractor.

0.3 QUALITY ASSURANCE

A. Qualifications. All work required under this Section shall only be performed by a contractor experienced with bentonite slurry trench method of construction. Such experience shall have been obtained within the preceding five years on projects of similar nature, complexity and scope as to the subject work. The Contractor's experience record shall be submitted to the Engineer in writing for review, verification and approval.

B. Tolerances

1. Guide Walls

- a. The finished face of the guide wall towards the trench, and on the side of the trench nearest the subsequent main excavation, shall be vertical and shall represent the reference line. There shall be no ridges or abrupt changes on the face, and its variation from a straight line or specified profile shall not exceed 1/2 inch in ten feet.
- b. The clear distance between faces of the guide walls shall be the width of the diaphragm wall plus not less than one nor more than two inches.

2. Diaphragm Walls

- a. The wall face to be exposed, and the ends of panels, shall be vertical within a tolerance of 1:80.
- b. A tolerance of four inches will be allowed for protrusions from the exposed face of the wall resulting from irregularities in the ground as excavated.
- c. Notwithstanding the above tolerances, the finished inside wall surface shall not encroach on the minimum clearances indicated.

3. Formed Recesses. Position formed recesses, and anchorage plates, pipe sleeves and other devices necessary for the temporary support system, within plus or minus three inches of the indicated location.

4. Reinforcing Steel Placement

- a. Normal to Wall: plus or minus one inch.
- b. Other Directions: plus or minus three inches.
- c. Dowels: plus or minus three inches from indicated position with respect to wall.

C. Bentonite Certificate. With each shipment of bentonite delivered to the site, provide the Engineer with a certificate from the manufacturer of the bentonite, stating from which consignment the material delivered to the site has been taken, and showing apparent viscosity range (centipoises), gel strength range (N/m) for solids in water, and methods of test used to determine these properties.

D. Control Testing of Bentonite Slurry. Perform control testing of bentonite slurry, using suitable apparatus to determine the following parameters:

1. Freshly Mixed Bentonite Slurry. Measure density of freshly mixed slurry as a check on the quality of slurry being formed. Calibrate measuring devices monthly, or more often if directed by the Engineer.
2. Bentonite Slurry Inside Trench Excavation. Perform tests specified below to verify properties of slurry inside trench excavations are within the specified limits. Take samples from various locations within the trench, and perform tests every two hours of work on each panel.

The Engineer may permit less frequent testing when test results show that a consistent working pattern has been obtained.

- a. Density, by mud density balance: 65-80 pcf.
- b. Viscosity, by March Cone Method: 30 - 90 seconds: Less than 20 cP.
- c. pH 7.0 to 11.0.
- d. Sand Content: Less than 4 percent.

3. Bentonite Slurry in Trench Prior to Placing Concrete. Immediately prior to placing concrete in any wall panel, take a sample of the slurry eight inches from the bottom of the trench, and test it for density. Modify or replace the slurry in the trench if the density of the sample is found to exceed 1.15 g/ml. Do not place any concrete in the trench until the density of the slurry at the trench bottom has been corrected not to exceed 1.15 g/ml. Additional tests, such as measurement of sand content and fluid loss, shall be performed if requested by the Engineer.
4. Maintain daily job records of tests.

0.4 PRODUCT DELIVERY, STORAGE, HANDLING AND DISPOSAL

- A.** Bentonite. Promptly remove used bentonite slurry from the work areas and dispose offsite in accordance with EPA regulations. Temporary collecting pond will not be allowed. Disposal of bentonite slurry in sewers, catch basins or any other water collecting opening will not be allowed.

0.5 JOB SITE CONDITIONS

- A.** Protection. Protect surfaces of adjacent structures, pavements, sidewalks and other facilities to prevent contamination of these surfaces by excavated material, bentonite and concrete. At the completion of diaphragm wall construction, restore adjacent exterior surfaces to essentially their original conditions, as acceptable to the Engineer.
- B.** Vibration Control. Vibrations coming from the removal of boulders, rock excavations, or other operations in connection with diaphragm wall construction shall be limited to prevent damage to adjacent buildings. The Engineer will monitor such vibrations by means of seismographs placed within or close to sensitive structures to be protected; such structures, and limiting criteria applicable thereto, shall be as specified in the Construction Specifications.

PART 2 - PRODUCTS

0.1 MATERIALS

- A.** Tremie-Placed Concrete: Comply with Section 03300 - CAST-IN-PLACE CONCRETE, with the following modifications and additional requirements:
 1. Class: 4000 - 3/4.
 2. Aggregate: ASTM C33, Size No. 7
 3. Cement Content: 7.5 sacks per cubic yard minimum
 4. Slump Range: 7 to 9 inches
 5. Air Content: Surface without exposed sides: None. Surface with exposed side: 4 percent plus or minus 1-1/2 percent.
 6. Provide mixtures containing a minimum of 10 percent fly ash conforming to ASTM C 618 and a plasticizing admixture conforming to ASTM C 494.
- B.** Lean Concrete Backfill: 1000 psi minimum compressive strength at 28 days, two sacks of cement minimum per cubic yard.
- C.** Bentonite: Meeting the requirements of the American Petroleum Institute Standard 13 and Part 1 "Quality Assurance" Article.

PART 3 - EXECUTION

0.1 EXAMINATION AND PREPARATION

- A.** The indicated depths of diaphragm walls have been estimated from available soil borings. Variations from indicated depths are to be anticipated to adjust for actual subsurface conditions.
- B.** When directed by the Engineer, and not less than four weeks prior to the start of excavation, drill an exploratory borehole at the center of each panel location, and at other locations as directed by the Engineer, to a depth at least fifteen feet below the indicated trench bottom elevation. Where the wall is indicated to be founded on sound bedrock, begin coring five feet above the indicated bedrock elevation; continuously core bedrock with NW core barrels to indicated depth. The method of drilling, rate of penetration, drilling techniques, and tools used shall be such as to minimize fracturing of the bedrock and maximize recovery of rock cores. Supply core boxes for transporting and storing rock cores as directed.
- C.** The Engineer, upon examination of the results of the exploratory boring, will determine the actual foundation elevation of each panel.
- D.** The Contractor shall evaluate existing soil conditions and propose a bentonite slurry that will provide suitable sidewall support.

0.2 GENERAL

- A.** Construct dustproof partition walls and areaway closure walls prior to the start of slurry wall work within existing areaways (sidewalk vaults).
- B.** Do not excavate next to an existing panel until concrete in the adjacent panel has been in place at least 72 hours, or until the concrete has achieved a strength of 1800 psi.
- C.** Conduct Work of this Section so as not to damage facilities or improvements that are to remain in place.
- D.** Perform preparatory work to discover, protect, maintain, relocate, and restore utility service facilities.
- E.** Employ construction methods that prevent the spillage of excavated materials, slurry, and concrete into utilities, streets, sidewalks, and other facilities.
- F.** Contractor shall be responsible for providing a watertight wall system as specified in Part 3 "Repair of Leaks" article.
- G.** Special care shall be taken to clean and scarify the panel joint in order to ensure watertightness and the capability of shear transfer the full height of the joint.
- H.** Install guide walls as shown or required, and remove and dispose of guide walls after completion of the slurry walls.
- I.** Employ slurry construction methods and systems that minimize overexcavation, fluid loss, overpours, and groundwater leakage.
- J.** Keep a clearance of at least three unexcavated or constructed panels between two 'open' panels.
- K.** Clean the bottom of excavated panels thoroughly prior to placement of rebar, soldier piles, and tremie concrete.
- L.** Employ excavation equipment and methods proven capable of removing obstructions without damaging the equipment and without resulting in unstable or collapsing excavations.

0.3 EQUIPMENT

- A.** Trench Excavation. Use equipment with capability to remove all material from the trench, so arranged as to permit the free vertical passage of slurry within the trench and to prevent development of suction or pressure, and such that excavations for the trench panels do not exceed specified tolerances.

- B.** Excavation Inspection. Use devices approved by the Engineer to demonstrate that the trenches are fully excavated to the required depth and width.
- C.** Slurry Mixing. Use equipment that produces a stable suspension of bentonite and water along with necessary mechanical agitation. Transport slurry to panels by means of a temporary pipeline or other methods approved by the Engineer.
- D.** Slurry Circulation. Use pumps and accessories that circulate and agitate the slurry throughout full depth of drilled panels without use of air.
- E.** Slurry Reclaiming. Use equipment that removes detrimental quantities of excavated material and other foreign material from slurry.
- F.** End Stops. Use end stops that are clean and have a surface that conforms to the excavation tool. Soldier piles installed as part of a permanent slurry wall may be used as end stops. The Contractor shall use excavation methods to ensure clean contact between the soldier piles and the tremie concrete.

0.4 INSPECTION AND TESTING

- A.** Use inspection devices in the presence of the Engineer before tremie concreting, to demonstrate that the trench has been completely excavated and that settled cuttings and excavated material have been removed. Complete neutral buoyancy rod testing for each panel to confirm that soil removal has been completed to the correct depth. Remove concrete from previous concreting operations which has flowed into trenches.

0.5 CONSTRUCTION

- A.** Construct slurry trench concrete walls of reinforced concrete, or plain concrete with embedded structural steel, installed by displacement of bentonite slurry from slurry filled trenches.
- B.** Excavate preparation trenches for the purpose of and in such manner as to discover, preserve, maintain, relocate and restore utilities and other obstructions in the vicinity of slurry walls. Employ construction methods such that slurry materials used during excavation of trenches and placing of concrete by tremie are contained and controlled to such extent as to prevent leakage and spillage slurry and excavated materials into adjacent vaults, basements, utilities, streets, sidewalks, structures or other facilities.
- C.** Excavate slurry wall trenches in panels of the indicated thickness and depth as directed by the Engineer, with a maximum panel length of 18 feet. Leave not more than the indicated number of slurry-filled panels at one time. Leave at least one unexcavated panel and one tremie concrete-filled panel,

with the concrete filled at least 72 hours old, between any two slurry-filled panels.

- D.** Perform panel excavations by combinations of drilling, clamping, scraping or other means approved by the Engineer. Use such means as will minimize over-excavation and loosening and caving of material outside designed trench width. Anticipate that boulders may be encountered in excavating for panels and provide procedures and equipment for their removal.
- E.** Mix bentonite with clean, fresh water at a temperature above 40 degrees F. Maintain panels full of slurry to within two feet of the top of guide walls, and at least three feet above the level of external standing ground water, during excavation operations and until the tremie concrete placement is essentially completed. Circulate or agitate the slurry during drilling and excavation operations and immediately prior to concreting. Maintain the slurry requirements at all times, including non-working periods and stoppages. Provide continuous circulation or agitation, if necessary, to meet these requirements.
- F.** Place concrete by tremie method as specified in Section 03300 - CAST-IN-PLACE CONCRETE.
- G.** Start placement of tremie concrete in excavated panels within eight hours of completion of excavating panels, and within two hours after placing steel, and proceed continuously until completion of concreting. If these time limitations are exceeded, remove steel, clean and reinstall.

0.6 PLACING STRUCTURAL AND REINFORCING STEEL AND CONCRETE

- A.** Place structural steel shapes as shown on the Drawings.
- B.** Prior to placing structural steel or reinforcing steel and concrete in the slurry filled trench, clean the joints of adjacent previously poured panels to create a watertight bond. In addition, the bottom of the trench shall be sounded in at least three spots in the middle and at both ends, with results recorded, and shall be cleaned of loose material to the satisfaction of the Engineer. The trench shall be inspected to determine that the required depth and width of excavation have been achieved.
- C.** Where end stops are to be used, insert end stops prior to placing concrete in a panel. They shall be adequately restrained to prevent movement in any direction prior to and during concrete placement. Steel soldier piles and pipes may be used as end stops. The contractor shall submit for approval the filler material to be used between the pile and the end of the excavation. The material shall be placed to prevent migration of tremie concrete around the pile and yet be easily removable during excavation of the adjacent panel. The soldier piles shall be firmly secured at the bottom of the excavation to prevent movement of the pile during concrete

placement. Contractor shall not forcibly twist a pile after seating it to obtain rotational tolerance.

- D.** Do not place structural steel or reinforcing steel assemblies that are distorted. Reinforcing steel assemblies and structural steel shall be within specified tolerances and securely held in place prior to and during concrete placement. As structural steel or the reinforcing steel assembly is lowered into the slurry-filled excavation, suitable guides and spacers shall be used. Alignment of blockout panels, brace plates, and other specified connections shall be protected and maintained during placement of the cage
- E.** Install casings and sleeves in slurry wall as indicated on the Drawings.
- F.** Place concrete by tremie method, either by gravity flow or by pumping, in such a manner that the concrete displaces the slurry progressing from the bottom and rising uniformly level to the required elevation. Overpour as necessary to remove laitance and contaminated concrete from the top surface. For reinforced concrete slurry walls, place concrete using at least two tremie pipes. For soldier pile tremie concrete (SPTC) walls, concrete shall be placed using tremie pipes centered between each soldier pile within the panel. The bottom of the tremie pipe shall be a maximum of 1 foot from the bottom at the start of concreting. Care shall be taken during concreting so as not to cause twisting of soldier piles from unbalanced loading. Tremie method shall comply with the applicable requirements of Section 03300 - CAST-IN-PLACE CONCRETE. Initially there shall be a suitable plug at the top of the tremie pipe to separate concrete from the drilling fluid. Also provide for a concrete discharge speed at the bottom, such that all material settled at the bottom after reinforcement placement shall be scoured and displaced by the concrete. Thereafter, a positive concrete head shall be maintained throughout the tremie process. Concrete placement shall proceed uninterrupted until completion of the panel.
- G.** After the initial charging with concrete, the bottom of the tremie pipe shall be embedded at least 5 feet into the concrete during placement, and this minimum depth shall be maintained throughout the placement.
- H.** The concrete level during placement shall be kept essentially horizontal. No horizontal movement of the tremie pipes shall be permitted. For soldier pile tremie concrete (SPTC) walls, the difference in the level of concrete on both sides of an individual soldier pile shall not vary by more than two feet to avoid movement and twisting of the soldier pile.
- I.** Concrete shall be placed in slurry excavations within two hours after placement of reinforcing and shall proceed uninterrupted until completion. Concrete shall be placed in restricted headroom conditions within 72 hours and elsewhere within 24 hours of completing excavation. The bottom of the excavation shall be cleaned by air lifting or pumping within one hour immediately prior to placing concrete. After being cleaned, the

bottom shall be sounded at several locations, to the satisfaction of the Engineer, prior to final acceptance of the bottom for concreting. Results of sounding shall be recorded with corresponding times of checking, and submitted to the Engineer.

- J.** Top of wall reinforcing steel shall be clean and free from any slurry and debris detrimental to future extension of the wall or roof.
- K.** Where end stops are to be removed, their withdrawal shall be accomplished after the initial set of the concrete takes place and such that no damage occurs to the concrete. The exposed wall joints shall be inspected and cleaned of laitance or deleterious materials.
- L.** Dropping or forcing reinforcing steel into slurry excavations shall not be allowed. If the reinforcing steel does not properly and smoothly enter the panel excavation, it shall be retrieved and excavation shall be checked as required. Repair or replace damaged reinforcing.
- M.** Protect sleeves and pipes to be embedded into the concrete during concrete placement.

0.7 INSPECTION AND REPAIR

- A.** Remove bentonite and polymer contaminated concrete from areas and lines where other construction is to join the slurry related construction.
- B.** Cut, patch, and repair structural defects. Remove concrete that projects beyond the tolerances shown for inside wall surfaces.

0.8 REPAIR OF LEAKS

- A.** Slurry walls shall be watertight, defined as free of seeping water leaks.
- B.** Repair of leaks shall be completed using an approved hydrophilic acrylic, polyurethane, or equal repair material.
- C.** The Contractor shall inspect for watertightness of slurring walls on a monthly basis, starting within two weeks after first exposure of the wall panels during excavation, and continuing until Final Acceptance. Inspection reports shall be submitted to the Engineer within one week following inspection.

0.9 BRACING SLURRY WALLS FOR SUPPORT OF STRUCTURES

- A.** Walers. Furnish and install walers, where required, at each level of braces. Place walers on inside face of slurry wall. Wedge, drypack and otherwise provide tight bearing between walers and slurry wall, with ample bearing areas to provide uniform transfer of load.

- B.** Preloading Braces. Preload braces at all levels to the amount of the computed maximum compressive force on the basis of diagrams of pressure indicated and consideration of the increased strut loads which may develop because of the removal of bracing as the structure is built. Accomplish preloading by approved procedures. Submit details of the proposed jacking procedures for review by the Engineer. Introduce the jacking load into the braces as soon as possible and in accordance with methods, procedures and sequence as described on the accepted working drawings. Coordinate excavation work with installation of bracing and preloading. Use steel shims and steel wedges welded or bolted in place to maintain preloading forcing in the bracing after release of jacking equipment pressure.
- C.** Any follow-on work to embedded soldier piles including cleaning, welding or bolting shall be completed with minimum vibration at the soldier pile/concrete interface.

0.10 REMOVAL OF BRACING

- A.** Leave the first level of bracing immediately above the invert slab in place for a minimum of 48 hours after the placement of concrete for the invert slab. Leave all other levels of bracing in place for a minimum of seven days after placement of the concrete to receive the transferred loading from the removed bracing. Remove the bracing supporting the sides of excavation in a manner that will not disturb or damage adjacent buildings, structures, construction or utilities. Immediately fill voids created by the removal of all or portions of the bracing with lean mix concrete. Demonstrate with strength test results that the concrete has reached sufficient strength before transferring the load from the bracing to the concrete structure.

0.11 CORRECTIVE ACTIONS

- A.** Seal leaks in the walls which are of sufficient size to permit penetration of fines and loss of soil, or which may cause boiling or other instability of the bottom of the excavation. Seal leaks using methods acceptable to the Engineer.

PART 4 - MEASUREMENT AND PAYMENT

0.1 MEASUREMENT

- A.** Concrete diaphragm wall, for indicated thicknesses, installed by the slurry trenches process through overburden will be measured by the square foot. For purposes of this measurement, overburden shall include all materials encountered including fill, sand, clay, glacial till, boulders, cobbles, decomposed rock and any other materials except rock as defined herein.

The length of the wall installed will be measured on the inside face, within the limits indicated or as otherwise directed. The height of the wall will be measured from the top of the 4,000 psi concrete indicated to the elevation where rock as defined below is encountered, or to the bottom of the wall where the wall is founded on other than rock.

B. Concrete diaphragm wall, for indicated thickness, installed by the slurry trench process through rock will be measured by the square foot. The wall will be measured on the inside face only within the limits indicated from the bottom of the wall through overburden as specified above to the final foundation elevation as indicated or as directed by the Engineer. For purpose of this measurement, rock is defined as material that satisfies both of the following:

1. It cannot be excavated nor removed by specifically designed bentonite slurry wall excavating tools, by grabbing, scraping or rotary-scraping action only.
2. Rock fragments only are consistently recovered by the above tools when used alone or after chiseling operations.

C. Lean concrete backfill will be measured by the cubic yard.

D. Exploratory boreholes required by the Engineer in excess of one at each panel location will be measured by the linear foot.

E. No separate measurement or payment will be made for the following:

1. Reinforcing or structural steel.
2. Guide walls and guide trench construction.
3. Sleeves, plates and embedded items for tieback settings, installations and other purposes.
4. One exploratory borehole drilled at each panel location.
5. Provisions for corrosion controls.

0.2 PAYMENT

A. Construction diaphragm walls will be paid for at the Contract unit price for the quantities determined as specified above.

0.3 PAYMENT ITEMS

ITEM NO.	DESCRIPTION	UNIT
0242.978	REINFORCED CONCRETE DIAPHRAGM SLURRY WALLS	SF
0243.014	LEAN MIX SLURRY TRENCH CONCRETE	CY
0243.020	EXPLORATORY BOREHOLES	LF

END OF SECTION

NOTES TO THE DESIGNER

- A.** Any request to modify or waive the specification requirements listed below must be approved in writing by the MBTA's Director of Design:
 1. Neutral buoyancy rod testing of slurry walls shall not be deleted.